PINHOLE DISK LAMINATE AND A PROCESS FOR PRODUCING THE SAME

BACKGROUND OF THE INVENTION

This invention relates to a pinhole disk laminate for use as an order sorting aperture (OSA) in hard x-ray microscopy using a Fresnel zone plate (FZP). The invention also relates to a process for fabricating the pinhole disk laminate.

According to the invention, the pinhole disk laminate is used as an OSA in highly energetic x-ray microscopy and this enables viewing of very fine structures that have defied observation by conventional x-ray microscopy (roentgenography) on account of its limited spatial resolution.

A potential application of the invention is in the medical field where it is expected to perform satisfactorily enough to take the place of conventional roentgenography. The invention also finds applicability to materials science, where the strong penetrating power of high-energy x-rays which characterizes hard x-ray microscopy is utilized to perform nondestructive inspection and analysis of heavy metals and thick metallic materials as exemplified by nondestructive inspection of nuclear fuel rods, etc.

When applied to biology, high-energy x-rays present so small damage to biosamples that the activities and internal structures of animal and plant can be observed on the site in a viable condition.

The OSA (hereunder referred to as a pinhole disk) is an essential optical element for the development of x-ray microscopes using a Fresnel zone plate (FZP). The existing x-ray microscopes using a FZP have performed satisfactorily well with the conventional thickness of pinhole disks and this is primarily because they use x-rays of low energy. For example, a single metal disk 9.5 mm in diameter have proved satisfactory if it has a round through-hole in the center with a diameter of 20 μm.

However, if the energy of the x-rays used is increased to near 100 keV, even a platinum pinhole disk is insufficient to stop (block) the unwanted hard x-rays diffracted from the FZP in hard x-ray microscopy as long as it has the insufficient thickness.

As shown in Fig. 1, the pinhole disk which is used as a component of a hard x-ray microscope receives hard x-rays coming from the left and the incident light is divided into two parts, one being condensed by a FZP and indicated by 1 in Fig. 1 and the other indicated by 2. The pinhole disk selectively transmits the condensed light 1 of a specified order but blocks the unwanted light 2.

One may think that the above-described problem of failure to stop the unwanted hard x-rays could be solved by increasing the thickness of the pinhole disk. However, making a 20 μm untapered through-bole in a single thick metal disk involves considerable technical limitations and pinhole disks fabricated by the conventional pinhole making technology has been unsuitable for the development of hard

x-ray microscopes using the FZP.

SUMMARY OF THE INVENTION

The present invention is characterized by bonding or welding a multiple of pinhole disks with the openings of their pinholes kept in alignment. To this end, a wire (e.g. a tungsten wire), a fiber or a pin is passed through the pinholes in the superposed disks which are then bonded (or welded) together with their pinholes kept in alignment. Alternatively, light such as laser light may be guided through the pinholes in the superposed disks which are then secured with their pinholes kept in alignment.

By using the method of the invention, one can fabricate a pinhole disk laminate that has an untapered deep enough hole to stop (block) unwanted hard x-rays. The thickness of the laminate can be adjusted by choosing the number of pinhole disks to be superposed.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates the function of a pinhole disk in a hard x-ray microscope using a FZP;

Fig. 2 shows a single pinhole disk both in a plan view (a) and in section (b);

Fig. 3 shows the step of bonding or welding two superposed pinhole disks with a wire or a fiber or a pin inserted through the pinholes to keep their positions in alignment;

Fig. 4 shows a pinhole disk laminate in a completed form; and

Fig. 5 shows the step of adjusting and determining

the relative positions of holes in a plurality of pinhole disks with the aid of light such as laser light.

DETAILED DESCRIPTION OF THE INVENTION

Figs. 2(a) and 2(b) show an example of the specifications of a single pinhole disk. The disk is made of platinum and has an outside diameter of 9.5 mm with a thickness of 200 μm. It has a round through-hole in the center which is 20 μm in diameter and 200 μm deep. This hole can be made by conventional electrical discharge machining technology, etc.

In the next step, a plurality of such pinhole disks are superposed and bonded or welded together. Fig. 3 shows an exemplary case in which two pinhole disks are superposed. The position in which these two pinhole disks are to be fixed is determined by inserting a straight wire, fiber, pin, etc. through the pinholes so that their positions will not be offset.

Subsequently, the surfaces of the pinhole disks (excluding the holes) are bonded or welded together. After the end of bonding or welding, the wire, fiber, pin, etc. is removed to leave a pinhole disk laminate behind in a completed form (Fig. 4).

If light such as laser light is used as a means of aligning the holes in a plurality of pinhole disks, the method shown in Fig. 5 is used; in this method, the intensity of the light passing through the holes is measured with a photodetector and the relative positions of the pinholes in the disks are so adjusted and determined as

to provide a maximum intensity.

According to the calculation made by the present inventors, the pinhole disk laminate of the invention can block 99.9% of 82 keV hard x-rays if it consists of two platinum pinhole disks superposed to give a thickness of 400 μm. This is sufficient data to prove the practical feasibility of the pinhole disk laminate as an OSA in hard x-ray microscopy using a FZP.

The hard x-ray microscope using a FZP is expected to achieve the highest spatial resolution of all the hard x-ray microscopes proposed to date and it can be realized by the invention of the pinhole disk laminate.